Fuel and Graphite Needs for VHTR

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Background

HTGR Technology Well Established

PROTOTYPE PLANTS

DRAGON – 20 MWt
(U.K.)
1964 1975

AVR – 46 MWt
(FRG)
1967 1988

PEACH BOTTOM 1 – 115 MWt
(U.S.A.)
1967 1974

HTTR – 30 MWt
(JAPAN)
1999 - present

HTR-10 – 10 MWt
(CHINA)
2000 - present

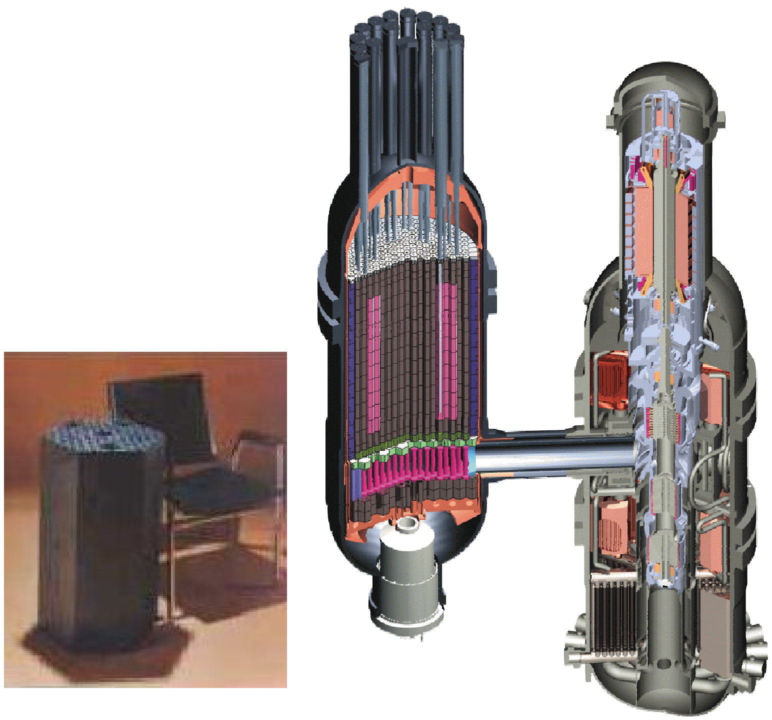
DEMONSTRATION PLANTS

FORT ST. VRAIN – 842 MWt
(U.S.A.)
1976 1989

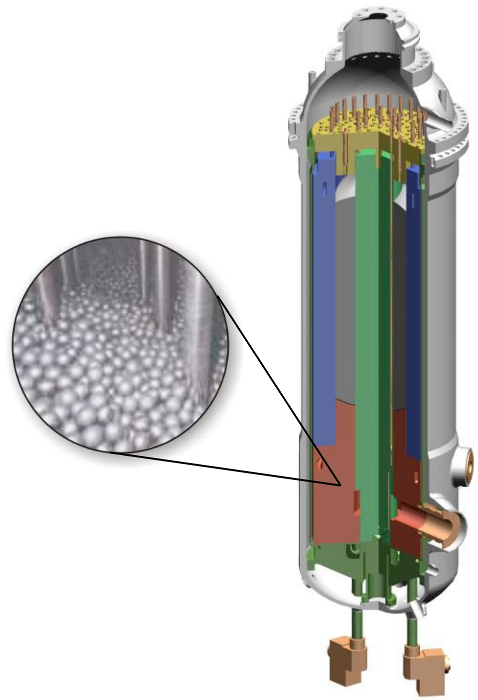
THTR – 750 MWt
(FRG)
1986 1989

Background

Two major design options: prismatic and pebble bed



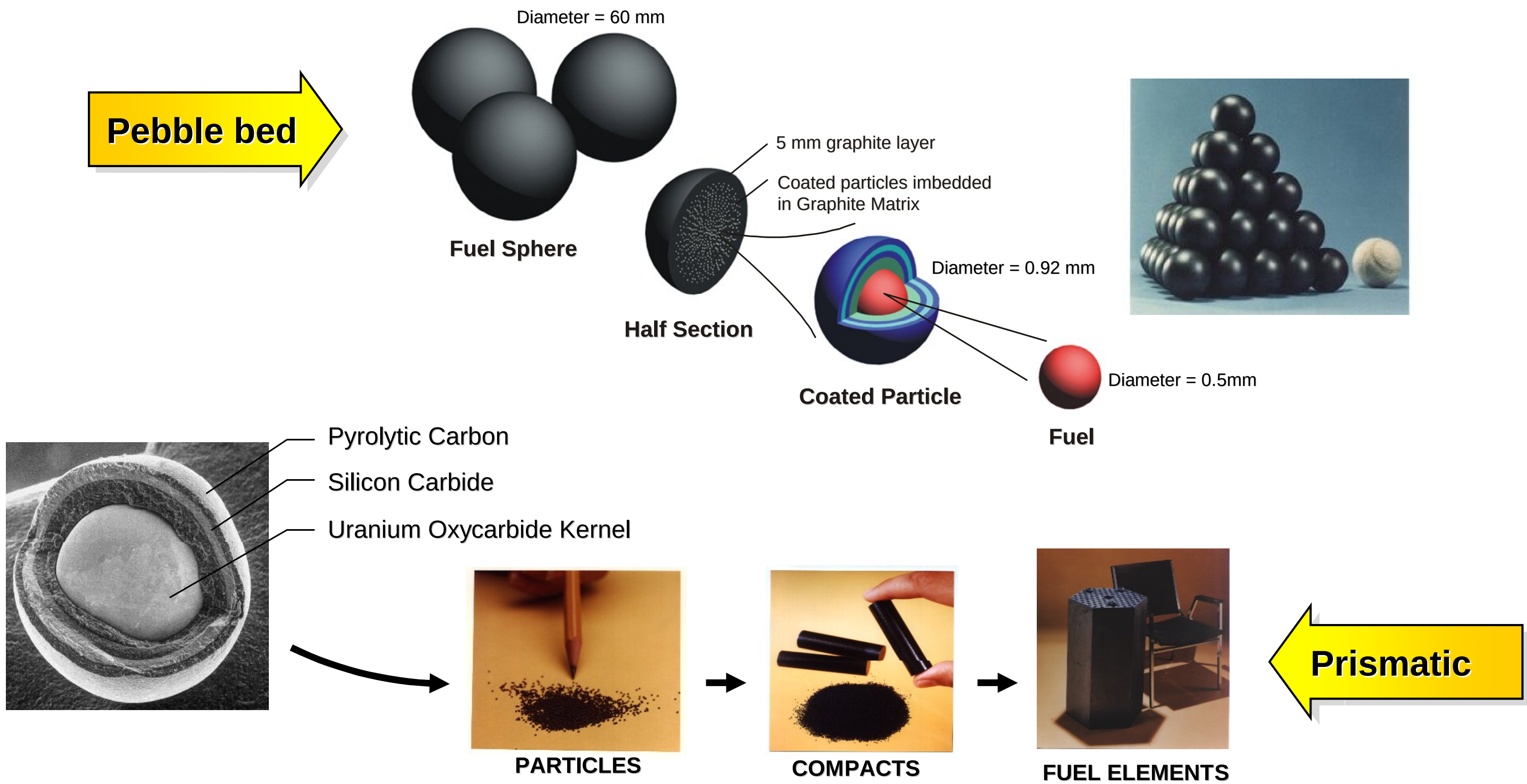
Prismatic
(Dragon, Peach Bottom, FSV, etc.)



Pebble-bed
(AVR, THTR, SA PBMR, China, etc.)

Background

All HTGRs Rely on Coated Particle Fuel



TRISO coating primary barrier for fission product release

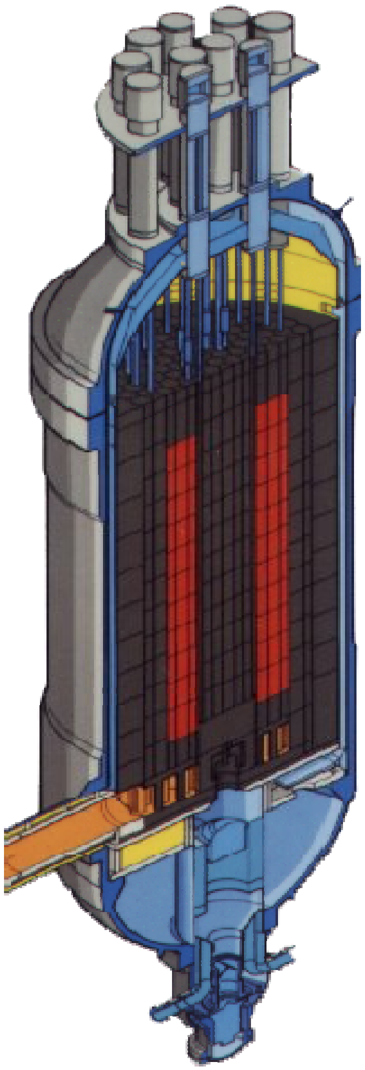
TRISO Coating Particle Fuels Needs

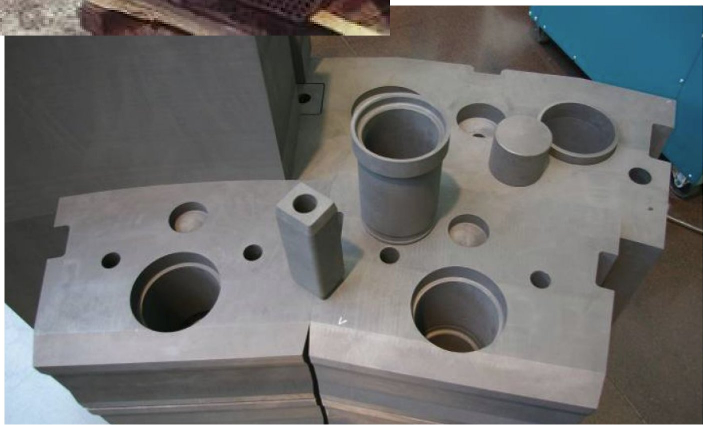
- Thermomechanical properties of coating layers and fuel element. Would require surrogate particles to accomplish
  - Pyrocarbon irradiation creep studies
  - Thermomechanical properties of coating layers to compare to historical values
- Irradiated material) thermal properties as a function of packing fraction, temperature and dose.
  - (compact matrix and inert surrogate compacts
  - (shrinkage, density, thermal conductivity heat capacity)
- Irradiated B_4C TRISO-coated particles to test pressure vessel failure models
- Temperatures: 800-1400°C, Dose: 2 to 5 x 10^{21} n/cm2 (E>0.18 Mev)

TRISO-coated Particle Fuels Needs

- Physio-chemical and fission product transport properties
- Separate effects tests on diffusivity of coating layers for various fission products unirradiated.
  - Probably would require custom-fabricated particles (probably would require collaboration with ORNL) of any particular kernel/coating combination.
- Irradiation of diffusion couple type geometry to understand interaction of key fission products with coatings (e.g. Pd, Ag, Cs, Te, I)
  - Need to get activity of key fission product correct to get right interaction rate
  - Would be good to determine concentration (e.g. burnup) dependence of interaction if possible
- Generation of irradiated coatings for out-of-pile diffusivity studies.
  - Irradiated coating physical and mechanical properties studies. Could run some inert surrogate particles to facilitate PIE.

Graphite Use in VHTRs





Graphite Irradiation creep issues

- A thorough understanding of underlying creep mechanisms for graphite material is required to understand experimental data, micromechanical modeling results, and predict whole core behavior.
  - **Pinning/unpinning mechanism for irradiation creep** – Viewed as primary mechanism for irradiation creep in graphite. Currently, there are doubts.
  - **Pore/crack interactions during irradiation** (i.e. closure of thermal cracks and the generation of new pores) – Generally believed to be on-set of turnaround and beginning of tertiary creep regime. Would like proof this is happening.
  - **Thermal creep verses irradiation creep mechanisms** – Is it irradiation induced or enhanced creep? Are mechanisms the same for thermal verses irradiation creep?
  - **Creep in tension vs. compression** – are they the same?

Graphite strength and fracture toughness

- A better understanding and predictive capability for determining the strength of graphite.
  - **Flaw (pore) size distribution –** Both irradiated and non-irradiated pore structure determination throughout the graphite components. Sizes of normal flaws (fabrication) and disparate flaws (from NDE methods) are required.
  - **Crack propagation after/during irradiation** – Graphite is a brittle material with fracture basically dependent upon flaw size and distribution within the microstructure. How does this interaction and crack propagation change with a changing pore structure during irradiation?

Other Needs

- **Irradiation response of composites (SiC-SiC primary; C-C is backup).** Control rod guide tube is major application
  - **Understanding of primary failure mechanisms –** How do they fail in tension (and compression)? How does irradiation affect the failure mechanisms (different dimensional changes between fibers and matrix creating more/larger flaws in microstructure)? Irradiated and non-irradiated testing is needed.
- **NDE Needs**
  - Physical degradation (cracks), material property changes (K in graphite), delamination of fiber-matrix (composites)
  - An irradiation to test the technique in-situ would be very interesting